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Response of the Engraver Beetle, *Ips Perturbatus*, to Semiochemicals in White Spruce Stands of Interior Alaska

Richard A. Werner

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Author

RICHARD A. WERNER is supervisory research entomologist, Pacific Northwest Research Station, Institute of Northern Forestry, 308 Tanana Drive, Fairbanks, Alaska 99775-5500.

Abstract

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Field tests on the efficacy of various scolytid bark beetle pheromones to attract *Ips perturbatus* (Eichhoff) were conducted from 1977 through 1992 in stands of white spruce (*Picea glauca* (Moench) Voss) in interior Alaska. Several pheromones attracted high numbers of *I. perturbatus* and species of the predator *Thanasimus* to baited funnel traps. Test results also indicated that attacks by *I. perturbatus* may be deterred by certain semiochemicals.

Keywords: Bark beetles, *Ips perturbatus*, semiochemicals, pheromones, aggregation pheromones, antiaggregation pheromones, insect management, white spruce, *Picea glauca*, Alaska (interior).

Summary

Date from 7 years of field tests on the efficacy of scolytid bark beetle pheromones to attract *I. perturbatus* are summarized. High numbers of beetles were caught in traps baited with racemic ipsdienol (+50:-50). The addition of *exo*-brevicomin to racemic ipsdienol increased the number of beetles caught by 97 percent in 1992 field tests. Racemic ipsenol consistently caught few beetles in baited traps. In 1987 when beetle populations were high, field tests using beetle deterrents showed that the addition of 2-methyl-3-buten-2-ol and racemic ipsenol to racemic ipsdienol in funnel traps reduced the number of beetles caught by 92 and 38 percent, respectively. The addition of either 2-methyl-3-buten-2-ol or racemic ipsenol to racemic ipsdienol reduced beetle catch by 88 percent in 1992 field tests when beetle populations were low. In 1991 field tests, species of the predator *Thanasimus* were caught by the enantiomers of ipsdienol tested alone or in combinations; however, the combination of racemic ipsdienol + (+) ipsdienol (+97:-3) + (–) ipsdienol (-3:+97) caught the most *Thanasimus*. Future research will concentrate on field tests to deter attacks by *I. perturbatus* with semiochemicals.

Contents

Introduction

The engraver beetle (*Ips perturbatus* (Eichhoff)) (Coleoptera: Scolytidae) usually is not a primary killer of spruce trees in Alaska but prefers to attack and colonize white spruce (*Picea glauca* (Moench) Voss) stressed by such disturbance as fire, periodic flooding, drought, logging, ice and snow damage, or wind. Wind-thrown and ice- or snow-damaged trees and logging slash are ideal breeding habitats (Holsten and Werner 1987). In most years, endemic populations infest individual standing trees, but during warm, dry summers after mild winters with above-average snowfall, beetle populations increase to such high levels that live, standing trees are infested and killed (Werner 1988). The average number of hectares infested annually in interior Alaska from 1978 to 1985 was 5060; however, high beetle populations killed trees over 6475 hectares in the Fairbanks area alone in 1986 and 1987 after a wildfire in 1983 and excessive ice and snow damage in 1985 (Holsten 1986). A record snowfall in the Fairbanks area in 1991 caused breakage of tree boles and tops in stands of white spruce. Observations of these trees during summer 1991 noted high levels of infestation by *I. perturbatus*. These populations reached epidemic levels during summer 1992 because winter temperatures and snowfall were above average. These recurring problems with epidemic populations of *I. perturbatus* prompted renewed research to develop new management strategies in addition to those described by Werner (1988).

The production of aggregation pheromones by pioneer beetles has been described for many scolytid species (Borden 1982). Species of *Ips* beetles aggregate on selected hosts in response to pheromones produced by males in the initial construction of egg galleries. Identification of pheromones from species of *Ips* started in 1966 when three terpene alcohols were identified as components of the pheromone for *I. paraconfusus* Lanier (then *I. confusus* LeConte) (Silverstein and others 1966a, 1966b; Wood and others 1966). These componds were (1) 2-methyl-6-methylene-7-octen-4-ol (ipsenol), (2) *cis*-verbenol, and (3) 2-methyl-6-methylene-2,7-octadien-4-ol (ipsdienol). Mori (1975, 1976) describes the absolute configuration of these compounds as (–) ipsenol and (+) ipsdienol. Neither compound was active alone, but a combination of ipsenol with either of the other two was active. These compounds and *trans*-verbenol are present in various combinations in several species of *Ips* (Renwick and Vite 1972, Vite and others 1972). Ipsdienol, ipsenol, and lanierone are the only biologically active, insect-produced compounds known from *Ips* (Bakke 1970, Teale and others). Monoterpenes of the host tree serve as precursors of the pheromones (Bakke 1975; Hughes 1973, 1974; Vite and others 1972; Vite and others 1974). These same compounds were implicated as pheromones of *I. confusus* (Young and others 1973). Vite and Renwick (1971) identified ipsenol as an aggregation pheromone for *I. grandicollis* (Eichhoff), and *I. calligraphus* (Germar) responds to a combination of ipsdienol and *cis*-verbenol along with host volatiles (Renwick and Vite 1972). Bakke and others (1977) identified ipsdienol, *cis*-verbenol, and 2-methyl-3-butene-2-ol (methyl butenol) as the aggregation pheromones of *I. typographus* (L.). *Ips pini* (Say) responds to the two enantiomers of ipsdienol (Birch and others 1980, Lanier and others 1980, Stewart 1975); whereas, *I. latidens* (LeConte) and *I. paraconfusus* Lanier respond to ipsenol (Lanier and Wood 1975).

The use of semiochemicals, bióactive message-bearing chemicals, to manipulate bark beetle populations has gained considerable interest during the last decade because of minimum environmental impact. This use includes synthetic host attractants and pheromones to either prevent attack or reduce the attack of bark beetles to a level below the threshold density required for the development of brood trees. This type of strategy has several advantages. First, the use of traditional insecticides could be minimized. Secondly, development of beetle resistance to treatment should be negligible because pheromones are part of the communication system of bark beetles. Lastly, there would be little direct mortality to parasites and predators as occurs with insecticide treatment.

Several objectives were developed and tested from 1977 through 1992:

1. To identify which scolytid bark beetle pheromones were attractive to *I. perturbatus* in interior Alaska.

2. To determine the efficacy of various enantiomers of ipsdienol and ipsenol to attract *I. perturbatus* to baited traps.

3. To determine the efficacy of several semiochemicals to deter attacks on white spruce stands, slash, and log decks by *I. perturbatus*.

Materials and Methods

Study Area Characteristics and Trap Placement

Mature white spruce stands 300 m in elevation in the Bonanza Creek Experimental Forest, 40 km west of Fairbanks, Alaska, were used for the studies. Trees were 165 years old with an average diameter of 30 cm, an average height of 36 m, and a stand density of 875 trees per ha. Shrub cover was sparse with only *Alnus crispa* (Ait.) Pursh and *Viburnum edule* (Michaux) Raf. occupying the sites. The climate of the area is strongly continental with an average temperature of -3.5 °C (range -50 to +35 °C). The average temperature during beetle flight is 16 °C. A different site was selected each year for each study to reduce the bias of unequal population size.

Semiochemicals were released from perforated polyethylene vials attached to cylindrical wire mesh sticky traps (Kline and others 1974) in the field tests from 1977 through 1980. Traps measured 45 cm in length and 25 cm in diameter and were constructed of 6.35-mm mesh wire screen. Traps were set on iron posts 1.5 m aboveground. The studies from 1985 through 1992 used slow-release formulations of semiochemicals dispersed from 12-unit Lindgren[1] multiple funnel traps (Lindgren 1983). Funnel traps were suspended from a nylon rope tied between two nonhost trees or white spruce <7.6 cm diameter at breast height so the collection container of the trap was 0.3 m aboveground. All traps were placed in a grid pattern at 30-m intervals. Beetles were collected from the traps weekly from mid-May to early July. The insects caught were placed in glass vials with 70-percent ethanol and taken to the laboratory for identification and total beetle counts. The various semiochemicals and their respective release rates used in the different studies reported in this paper are shown in tables 1 through 4. Semiochemicals were purchased commercially and releasers prepared in the laboratory for the studies from 1977 through 1980; studies thereafter used slow-release formulations of semiochemicals. All semiochemicals used in the field tests had a chemical purity above 98.6 percent.

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[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Experimental Design

Treatments for all field tests were replicated five times in a randomized complete block design. Traps were rotated randomly each week to reduce the effects of host terpene attraction from adjacent live white spruce trees and spillover of beetles into these trees. Treatments consisted of semiochemicals in traps with unbaited traps as controls.

Statistical Analyses

Data were tested for homogeneity and, if nonhomogenous, were transformed by using a parametric test to overcome variations due to zero counts. Total numbers of *Ips* and *Thanasimus* beetles caught for each of the treatments were analyzed by using ANOVA. Differences between means were tested by using Tukey's (1953) studentized range (HSD) test ($P = 0.05$).

Results and Discussion

Field tests from 1977 through 1980 compared beetle response to racemic ipsdienol (+50:-50) and racemic ipsenol (+50:-50) with response to pheromones from other scolytids (table 1). Sticky, cylindrical, wire traps baited with racemic ipsdienol caught significantly more *I. perturbatus* than did other treatments. Racemic ipsdienol caught 58 to 64 percent more beetles than other scolytid pheromones did during years when beetle populations were low (table 1). Few beetles were caught in traps baited with racemic ipsenol, and no beetles were caught with *cis*-verbenol or *trans*-verbenol.

Further field tests were conducted in 1987 with commercial baits in slow-release formulations. These tests compared the efficacy of racemic ipsdienol (0.4 mg per day), racemic ipsenol (0.4 mg per day), and 2-methyl-3-buten-2-ol (17-20 mg per day). In these tests, Lindgren funnel traps baited with racemic ipsdienol caught 84 percent more beetles than racemic ipsenol alone and 62 percent more beetles than the combination of racemic ipsdienol and racemic ipsenol (table 2). Racemic ipsenol repeatedly caught few beetles in replicated field tests from 1977 to 1992. The addition of racemic ipsenol and 2-methyl-3-buten-2-ol to racemic ipsdienol reduced beetle catch by 38 and 92 percent, respectively.

As a result of the 1987 field tests, racemic ipsdienol released at a rate of 0.4 mg per day was recommended as a bait in funnel traps and on trap trees to trap out populations of *I. pertubatus* before and after logging operations in interior Alaska (Werner 1988). The recommendation stated that traps should be spaced at 30-m intervals when used in barrier trapping around clearcuts and selective cuts and around log decks, and at 60-m intervals when used in preharvest and postharvest trapping. Baited trap trees should be spaced at 60-m intervals in stands before timber harvest and trap decks at 30-m intervals along rights-of-way clearings.

Racemic ipsdienol released at a rate of 0.4 mg per day was used to bait trap trees and log decks after logging operations in interior Alaska from 1987 to 1991; however, the number of beetles trapped was low compared to the number of beetles caught in Lindgren funnel traps baited with racemic ipsdienol at a release rate of 0.2 mg per day, which was used for monitoring populations of *Ips*. The difference in beetle catch could be related to the different release rates or the different spacings between traps and between trap trees or log decks.

An additional field test was done in 1991 to further compare the efficacy of the enantiomers of ipsdienol; that is, racemic ipsdienol, (+) ipsdienol, and (–) ipsdienol. Racemic ipsdienol caught 98 percent more beetles than (+) ipsdienol and 64 percent more beetles than (–) ipsdienol (table 3). All enantiomers of ipsdienol and combinations except (–) ipsdienol alone attracted *Thanasimus*; however, the combination of racemic ipsdienol + (+) ipsdienol + (–) ipsdienol caught the most beetles (25 percent of 538 *Thanasimus* caught). The 1991 field test also investigated the response of recently emerged adults to the enantiomers of ipsdienol before these adults entered their overwintering sites. *Ips perturbatus* adults were caught from May 12 through June 25 with peak flight the week of May 26. No newly emerged *I. perturbatus* adults were caught during August and September, which indicates no response to the ipsdienol enantiomers at this stage of development. This study confirmed previous results that racemic ipsdienol at a release rate of 0.2 mg per day is more attractive to *I. perturbatus* than the other enantiomers or combinations of enantiomers.

Based on results from the 1987 field tests, a field test was conducted in 1992 to determine if certain semiochemicals deterred the response of *I. perturbatus* to racemic ipsdienol. The addition of various semiochemicals to racemic ipsdienol reduced beetle catch in funnel traps as follows: 2-methyl-3-buten-2-ol and racemic ipsenol by 88 percent, 3-methylcyclohex-2-enone (MCH) by 31 percent, and verbenone by 19 percent; however, the addition of *exo*-brevicomin increased beetle catch by 97 percent (table 4). Birch and Wood (1975) found that *I. pini* and *I. paraconfusus* are not cross-attractive although they attack the same host trees at the same time. Ipsenol from male *I. paraconfusus* inhibits the response of *I. pini* to male *I. pini*; whereas, linalool from male *I. pini* reduces the catch of *I. paraconfusus* in response to male *I. paraconfusus*. Borden and others (1991) found that verbenone + ipsenol reduced the number of logs attacked by *I. pini* by 66.7 percent and a 98.8 percent reduction in attack density. Livingston[2] also found in 1992 field bioassays that the addition of racemic ipsenol to the aggregation pheromones racemic ipsdienol + lanierone reduced the number of *I. pini* caught by 70 percent. The addition of racemic ipsenol + verbenone in combination to racemic ipsdienol + lanierone decreased trap catch by 95 percent.

Conclusions

Seven years of field testing on the efficacy of various semiochemicals on *I. perturbatus* was completed in 1992. *Ips perturbatus* were attracted to Lindgren funnel traps baited with racemic ipsdienol alone at release rates of 0.2 and 0.4 mg per day and *exo*-brevicomin + racemic ipsdienol at a release rate of 0.2 mg per day. Racemic ipsdienol (0.2 mg per day) currently is recommended for use in Lindgren funnel traps, and trap trees and log decks. The addition of 2-methyl-3-buten-2-ol (3.8 mg per day) and racemic ipsenol (0.2 mg per day) to racemic ipsdienol in funnel traps reduced the number of beetles caught compared to traps baited with racemic ipsdienol alone.

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[2] Personal communication, December 8, 1992, R. Ladd Livingston, Idaho Department of Lands, Coeur d'Alene, ID 83814-0670.

Parent and new brood adults did not respond to baited pheromone traps upon emergence from host trees in August but did respond the following spring when beetles emerged from overwintering sites. Species of the predator *Thanasimus* were caught by the enantiomers of ipsdienol tested alone or in combinations; however, the combination of racemic ipsdienol + (+) ipsdienol + (-) ipsdienol caught the most *Thanasimus*. Future research will concentrate on field tests to deter attacks by *I. perturbatus*.

Metric and English Units of Measure

When you know:	Multiply by:	To find:
Celsius (°C)	1.8 and add 32	Fahrenheit
Centimeters (cm)	2.54	Inches
Hectares (ha)	2.47	Acres
Kilometers (km)	0.621	Miles
Meters (m)	3.281	Feet
Millimeters (mm)	0.254	Inches

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Appendix

Table 1—Total number of *Ips perturbatus* caught in cylindrical sticky traps by synthetic scolytid pheromones, Fairbanks, Alaska, 1977-80

Treatment	Beetles caught[a] 1977	1978	1979	1980
	Number			
Frontalin	3d	105d	92d	397b
Frontalin + alpha pinene (1:1)	2d	234d	187c	243d
Alpha pinene	0d	66e	32e	143d
Seudenol	10d	85e	101d	374c
Seudenol + alpha pinene	3d	166d	218c	423b
Cis-verbenol	0d	0f	0e	—
Trans-verbenol	0d	0f	0e	—
Racemic ipsenol	125c	144d	236c	429b
Racemic ipsenol + alpha pinene	101c	384c	54d	207d
Racemic ipsdienol	423a	995a	564a	721a
Racemic ipsdienol + alpha pinene	112c	618b	144d	311c
Racemic ipsenol + racemic ipsdienol	231b	704b	377b	660a
Racemic ipsenol + racemic ipsdienol + alpha pinene	183b	466c	266c	312c
Sulcatol + alpha pinene	99c	156d	88d	49e
Unbaited control	0d	25f	15e	49e

— = no data were collected.
[a] Values followed by the same letter within columns are not significantly different ($P < 0.05$, Tukey's [1953] studentized range test [HSD]).

Table 2—Effect of 2-methyl-3-buten-2-ol and racemic ipsenol on the response of *Ips perturbatus* to racemic ipsdienol dispersed from Lindgren funnel traps, Fairbanks, Alaska, 1987

Treatment	Release rate	Beetles caught[a]
	Mg per day	*Mean number ± SD*
Racemic ipsdienol	0.4	2,286 ± 276a
Racemic ipsenol	.4	373 ± 46c
2-methyl-3-buten-2-ol	17-20	86 ± 11d
Racemic ipsdienol + racemic ipsenol	.4	1,420 ± 116b
Racemic ipsdienol + 2-methyl-3-buten-2-ol	.4	185 ± 23c
Racemic ipsenol + 2-methyl-3-buten-2-ol	.4	248 ± 35c
Racemic ipsdienol + racemic ipsenol + 2-methyl-3-buten-2-ol	.4	1,517 ± 154b
Unbaited control	—	384 ± 61c

[a] Values followed by the same letter are not significantly different ($P < 0.05$, Tukey's [1953] studentized range test [HSD]).

Table 3—Number of *Ips perturbatus* and *Thanasimus* spp. caught in Lindgren funnel traps by combinations of enantiomers of ipsdienol, Fairbanks, Alaska, 1991

Treatment	Beetles caught[a]	
	I. perturbatus	*Thanasimus*
	--- *Mean number* ± *SD* ---	
Racemic ipsdienol	7.30 ± 35.83a	3.12 ± 2.9b
(+) ipsdienol (97:3)	.13 ± 0.47d	2.64 ± 1.2b
(–) ipsdienol (3:97)	2.62 ± 11.25c	.56 ± 0.32c
Racemic ipsdienol + (+) ipsdienol	.75 ± 2.17d	2.20 ± 2.6b
Racemic ipsdienol + (–) ipsdienol	4.30 ± 11.31b	2.36 ± 3.2b
(+) ipsdienol + (–) ipsdienol	1.98 ± 4.10c	2.56 ± 1.0b
Racemic ipsdienol + (+) ipsdienol + (–) ipsdienol	.75 ± 1.35d	5.52 ± 4.1a
Unbaited control	.73 ± 2.76d	.64 ± 0.29c

[a] Release rates were 0.2 mg per day. Values followed by the same letter are not significantly different (P < 0.05, Tukey's [1953] studentized range test [HSD]).

Table 4—Effect of various semiochemicals on the response of *Ips perturbatus* to racemic ipsdienol dispersed from Lindgren funnel traps, Fairbanks, Alaska, 1992

Treatment	Release rate	Beetles caught[a]
	Mg/day	*Mean number* ± *SD*
(–) verbenone (+13:-87)	5.0	0.00 ± 0.00a
MCH	5.0	.00 ± 0.00a
2-methyl-3-buten-2-ol	3.8	.25 ± 0.05a
Racemic ipsenol	.2	.25 ± 0.05a
Exo-brevicomin	.2	2.00 ± 0.50ab
Racemic ipsdienol	.2	6.50 ± 1.65ab
Racemic ipsdienol + 2-methyl-3-buten-2-ol	—	.75 ± 0.15a
Racemic ipsdienol + racemic ipsenol	.4	.75 ± 0.15a
Racemic ipsdienol + MCH	—	4.50 ± 1.00ab
Racemic ipsdienol + verbenone	—	5.25 ± 1.25ab
Racemic ipsdienol + *exo*-brevicomin	—	12.75 ± 2.55b
Unbaited control	—	.00 ± 0.00a

[a] Values followed by the same letter are not significantly different (P < 0.05, Tukey's [1953] studentized range test [HSD]).

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Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208